

# Development of Rain Drop Removing Device of Rear Camera (Cleancam®)

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## Abstract

Although recently rear cameras have been widely used, there has been a phenomenon that visibility is lowered by water drops attaching to a lens of a camera when driving in rainy conditions as user frustration. In response, a water repelling treatment of a lense has been known, but the effect is not sufficient. Therefore, we worked on the development of a product (Cleancam®) that can remove water drops by spraying air onto a lens of a camera. In view of use by users and mountability on existing vehicles, we determined target specifications and requirements while performing a simulation and an on-vehicle evaluation, and developed the product. This paper mainly introduces efforts for developing a pump unit and a nozzle that are especially important parts.

## 1. Introduction

In recent years, technological development of Advanced Driver Assistance System by which a vehicle assists driving for a driver is in progress. On-vehicle camera, one of devices which configure ADAS, has spread as view camera for the driver to check the situation around the vehicle. Main product of view camera is a rear camera. In America, KT law (Kids and Transportation Safety Act) was enacted, and installing rear camera was obligated to all new vehicles from 2017, which promotes to further spread.

## 2. Background of development

Rear camera has a problem that the visibility extremely is lowered by water drop attached to the lens because it is mounted outside vehicle under environment with wind and rain. (Fig. 1)



Fig. 1 Image Captured by Camera Having Lens with Water Drop

In in-house driving tests, we found that water drop which lowers the visibility become gradually larger on the lens while driving by repeating spray (droplets of water) which is generated by raising water on the road surface by the own vehicle tires. (Fig. 2)

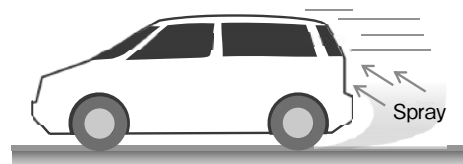


Fig. 2 Water Drop Attachment during Driving

This lowering of the visibility is well known as one of user frustration. As water repellent coating of lens surface is one of measures, but it is inadequate to prevent water drop attachment, and it is difficult to remove water drop without any kind of external force.

Then we developed rain drop removing device (Cleancam®) which adopted an air spray method which can add external force to water drop without damage to lens surface, and introduce the contents of it.

### 3. Product configuration and System

In this product, compressed air, which is generated by pump, sent to the nozzle through hose, and injected from the nozzle placed on the top of lens, blows water drop off. (Fig. 3)

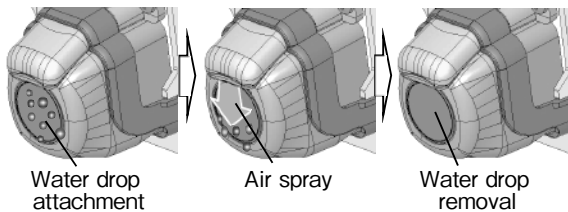


Fig. 3 Mechanism of Water Drop Removal

Product mainly consists of a camera with nozzle, a pump unit and a pump bracket. (Fig. 4)

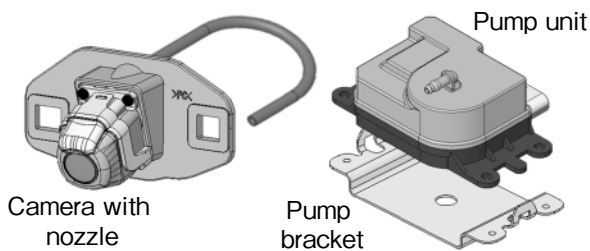


Fig. 4 Product Configuration

The pump unit is attached with the pump bracket to outer panel, which is inside of back door of vehicle, and sends compressed air to the nozzle placed on the top of camera from hose which penetrates through the back door panel. (Fig. 5)

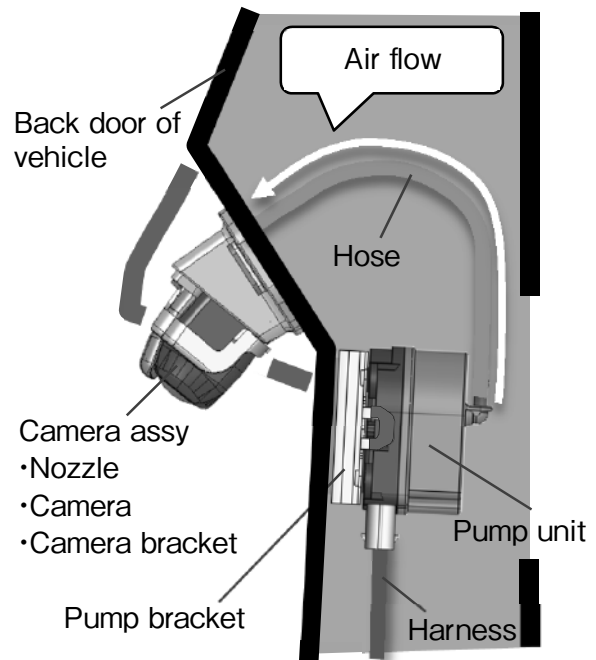


Fig. 5 Vehicle Mounting Condition

### 4. Specification study

We thought it is preferred as for the timing of water drop removal that removing finishes by rear camera image indicated on display considering user's usage, and we use the driver's operation as the trigger of system, which moves shift lever to the reverse position. Also, the system can provide manual spray in case of operation by the will of driver.

As for the range of water drop removal, we thought that utmost priority for the driver is the confirmation of the objects located in the reverse driving direction. Thereby we defined inside of guide line on the display as "priority area", and we target the ratio of water drop removal 90% or more. (Fig. 6)



Fig. 6 Priority Area of Water Drop Removal (Hatching Part)

## 5. Development of pump unit

Main issues of the pump unit development are the following.

- ① Stabilization of operation and securing durability
- ② Downsizing of device
- ③ High efficiency of spray (prevention of air leak)
- ④ Reduction of time from operation to spray
- ⑤ Prevention of drawing water while intake

We adopt rotation type impeller structure as the most important air compression part in the pump unit instead of general piston structure as shown below. (Fig. 7)

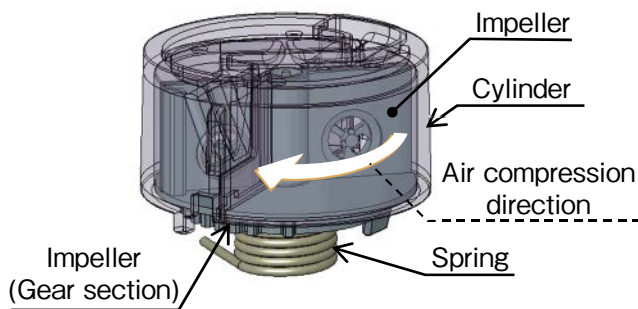


Fig. 7 Structure of Air Compression Part

This impeller structure enables the improvement of durability by changing all operation including motor as power supply, gear train, and air compression part into highly stable rotational motion. This structure is suitable for downsizing of the product because of the feature that is no ejection of driving body from the cylinder during intake operation like piston structure.

The impeller needs clearance between it and cylinder for smooth rotation. However, as the clearance causes the air leak (low spray pressure), we adopted the structure to reduce the clearance without increase of sliding load by the installing movable spacer between cylinder and impeller. (Fig. 8 and Fig. 9)

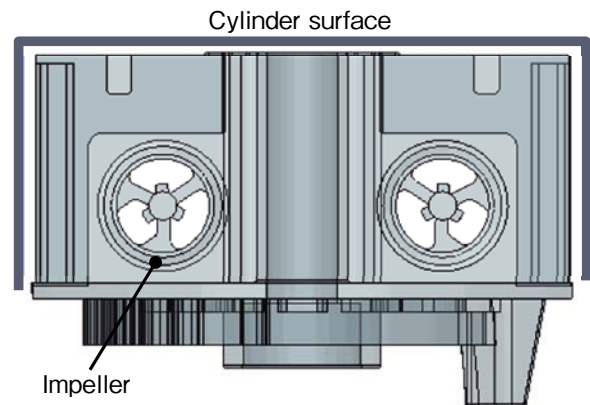
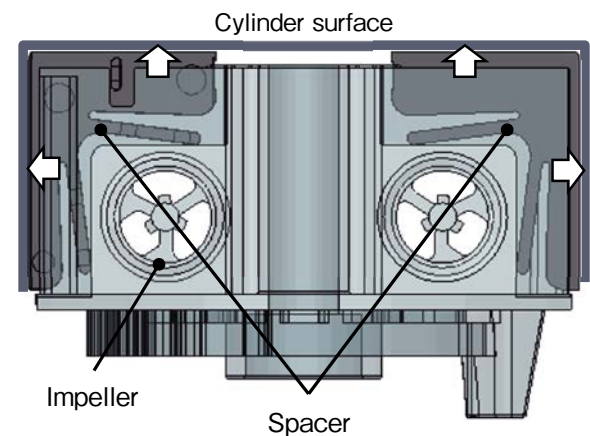


Fig. 8 Clearance between Impeller and Cylinder Surface (Without Spacer)



⬅ : Bias direction to cylinder

Fig. 9 Clearance between Impeller and Cylinder Surface (With Spacer)

Next, we explain a series of operations to supply compressed air to the nozzle.

The arrangement of gear is shown in Fig. 10, and driving power transmits from motor to impeller via gear train.

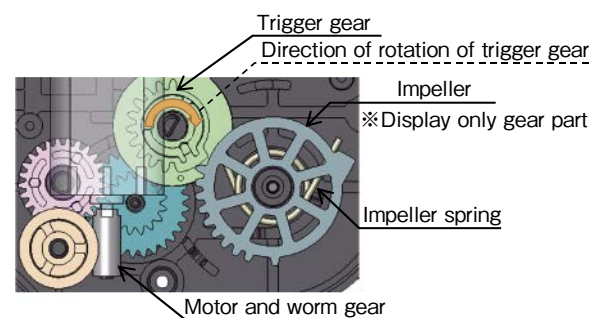


Fig. 10 Layout of Gear Train

- The series of operations are as follows. (Fig. 11)
- (a) Waiting at the state of intake completion to reduce time from spray operation to spray starting.
  - (b) Being out of gear right after rotation of gear by trigger input, then impeller rotates by spring force and spray starts.
  - (c) Engaging gear again after spray completion, and operation backs to (a) after intake operation.

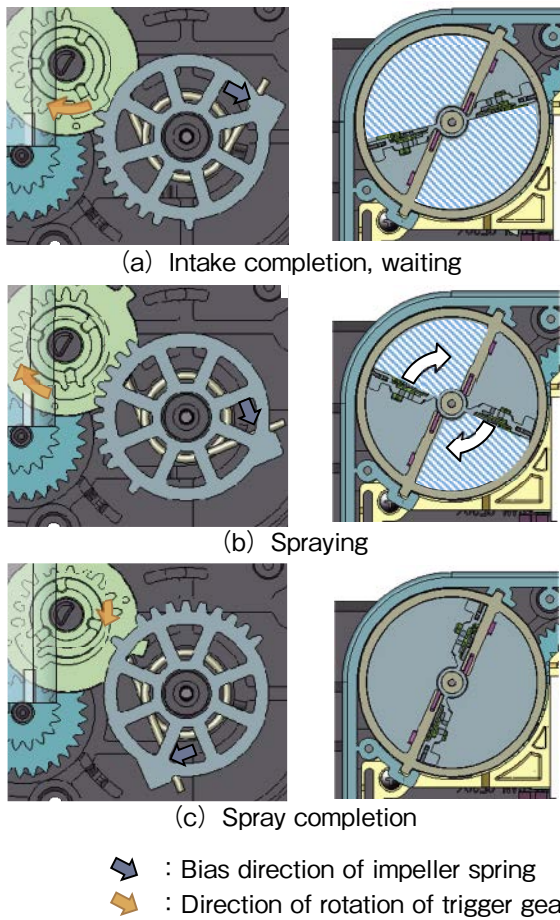


Fig. 11 Gear Drive

Lastly, we explain the path to take in the air to the pump.

As it is possible to take in the air from the nozzle, but there is a problem to spray water drop together with air to lens surface by drawing water drop attached on spray opening while intake. we build an intake opening on the pump unit side. (Fig. 12)

The air which entered from the intake opening flows into cylinder through internal chassis of pump unit, and flows to hose from upper side of cylinder.

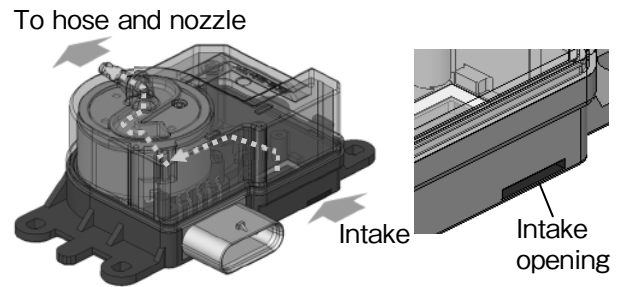


Fig. 12 Flow of Air

## 6. Development of nozzle

As for the requirement for the nozzle, jet stream efficiently spreads through lens surface with constant flow velocity and pressure, also as for the requirement for the mounting, there are restrictions such as arrangement of spray opening, size of outer shape and size as follows.

- ① Easy installation for exiting camera
- ② Easy mounting without any work of vehicle
- ③ Camera captures no nozzle image
- ④ No serious change of camera mounting position

The arrangement which satisfies the conditions is limited to the space as shown in Fig. 13. Then, the nozzle is required that it is thin with the thickness of 3mm or less, and the spray opening is positioned at the edge of top part of lens. In such condition, we have to realize efficient spray.

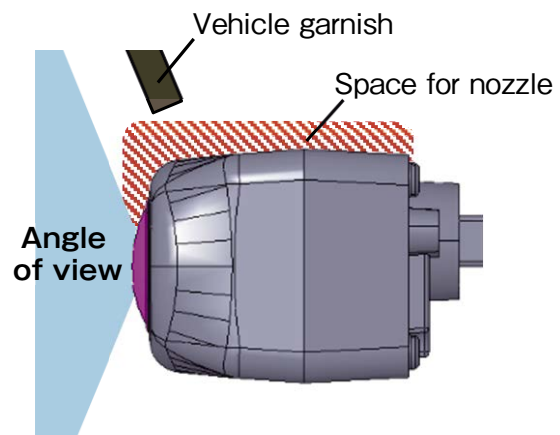


Fig. 13 Mounting Space for Nozzle

To increase flow velocity of the jet stream, in terms of cross-sectional area, spray opening is necessary to be designed smaller than round type cross-sectional inlet which is connected to the hose.

And we thought that thin and wide type spray opening shape is preferred so that the jet stream uniformly and widely spread over the lens surface with short spray distance from lens. (Fig. 14-1)

Also we designed flow path of which cross-sectional shape didn't change suddenly in order to reduce the loss through it between the inlet and the spray opening. Furthermore, we determined the final shape of spray opening to improve removal capability based on the verification result of flow simulation and confirmation of removal performance in actual product for various spray opening shapes. (Fig. 14-2, Fig. 14-3)

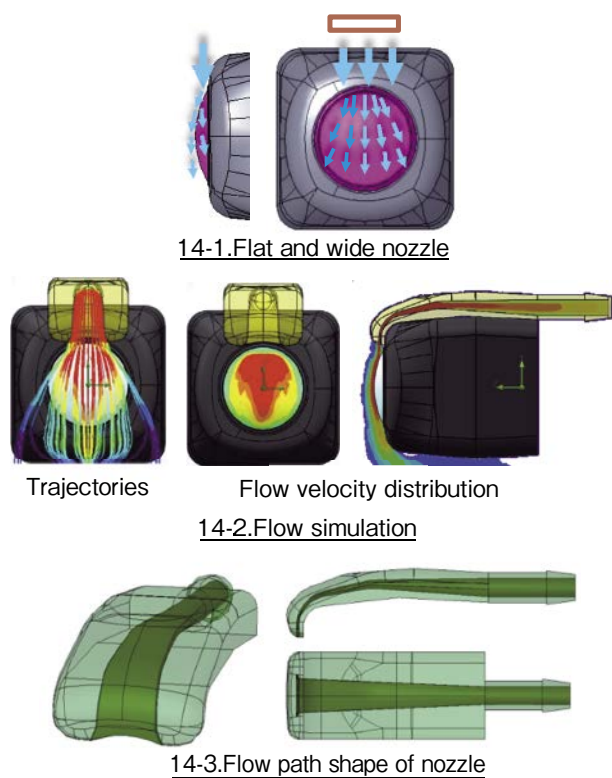


Fig. 14 Determination of Nozzle Shape

We evaluated removal performance of water drop by combination of this nozzle and the pump unit mentioned above.

Evaluation is carried out by reading the area ratio as "removal rate" that is calculated from priority area (within red frame) on display and the area in which water drop is removed, after attached water drop uniformly to all over the surface of lens.

We confirmed achieving removal rate of 90% or

more and securing enough visibility by the result of evaluation. (Fig. 15)

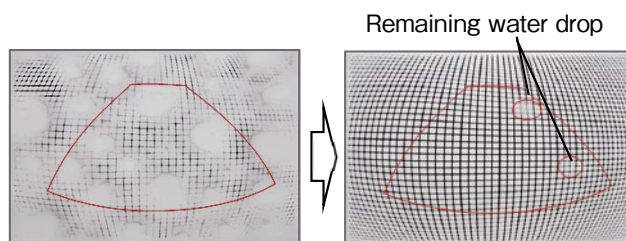
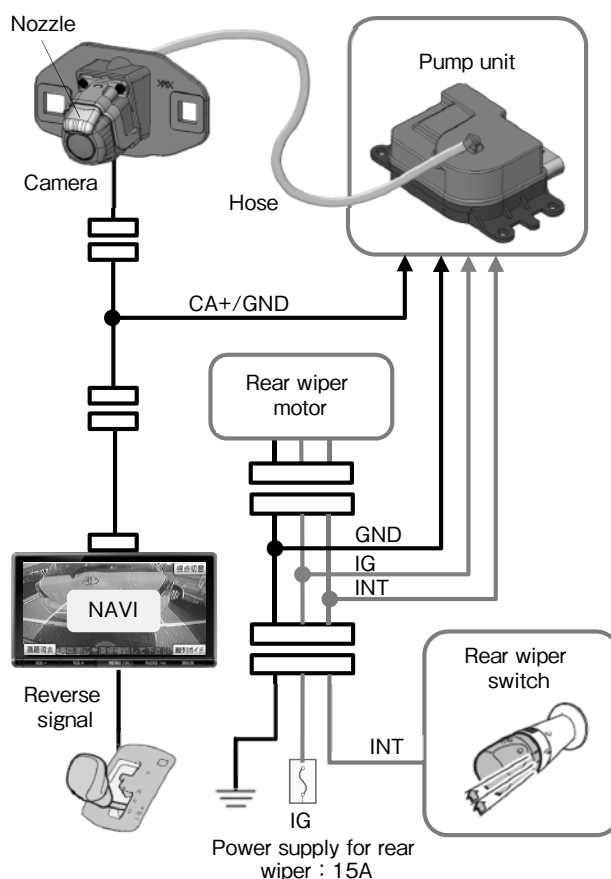


Fig. 15 Image Captured by Camera before and after Spraying to Air onto Lens

## 7. The Interface to vehicle

Other issue of this development is electrical connection to vehicle. (Fig. 16)



### Explanation of signal

- IG : Power supply
- INT : Trigger for spray (driver operation)
- CA+ : Trigger for spray (linked with reverse)

Fig. 16 Connection to Vehicle

In order to operate Cleancam, power supply for pump unit, spray linked with reverse operation as mentioned before, and trigger signal to spray by the operation of driver are required.

Considering mounting operability, it is preferred that these wiring is completed inside back door which is close to mounting position of the pump unit, we think.

As for the power supply, we use the power supply for rear wiper located in back door. This satisfies voltage and current for the operation condition of the pump unit, and we finally decided to use this power supply by considering it does not block any function of vehicle side by the voltage down and others while operation.

We use exiting power supply for rear camera as the trigger signal for spray linked with reverse operation. Power supply for rear camera can be used for the trigger signal because of switching ON-OFF linked with reverse operation, and it is easily divided because the wiring is located inside back door.

We use the signal of rear wiper switch as the trigger signal for spray by driver operation, which we think is optimal because a driver is familiar to operate the wiper in case of rain when spray is mainly carried out, and it is easily connected inside back door.

## 8. Future issues

As mentioned in the introduction, on-vehicle camera has been widely utilized also to sensing application, it is used as a device assisting autonomous driving. In such case, as there are problems such as no detection of target object or miss-detection by rain drop or stain, and there is limitation of the algorithm to resolve it, the application of function like Cleancam is effective solution for them.

On the other hand, when we consider to apply Cleancam to Multi-Angle Vision™ and camera monitoring system (CMS) as a successor of rear-view mirror, further downsizing is needed for improving ease of mounting because mounting place is not limited in rear of vehicle. Also, technology that timely removes water drop during normal

driving other than reverse driving is expected in future.

At this time, we proceed with development focusing on the function of rain drop removal. However, according to the future trend, we would like to respond to mud stain that are required in the overseas market, and proceed with product development which is combined with technology detecting attachment of rain drop and stain.

## 9. Conclusion

We achieved improvement of visibility of rear camera in rainy days, which was a potential problem. As a result, we proceeded with the development which contributed safe and comfortable drive.

We would like to contribute for realizing further comfortable mobility society by developing the product which satisfies user needs and expectation.

We would like to express our appreciation to many people for the cooperation of developing this product.

- Cleancam® is the trade mark of DENSO TEN Limited.
- Multi-Angle Vision™ is a trademark of DENSO TEN Limited.

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